10/563461
IAP15 Rec'd PCT/PTO 05 JAN 2006

GEAR TRANSMISSION UNIT WITH PLANET CARRIER

This invention relates to a planet carrier for a gear transmission unit and in particular, though not exclusively, to a planetary type gear transmission unit. It may be applied to a gear transmission unit for a wind turbine.

There is a continuing demand for larger wind turbines especially for offshore sites due to scarcity of suitable sites and cost of civil works. At the same time the requirements for reduction of size and weight of the machines and their components become more and more important. Typically a wind turbine rotor drives the low speed shaft of a gear transmission unit, which transforms torque and speed of the rotor to the required torque and speed of an electrical generator.

Integration of the components in a wind turbine is a way to reduce the weight and to make the drive assembly more compact, but it is important that the design and execution of the drive assembly avoids mutual interference of the external and internal loads on the different components. It is also important that the construction of an integrated drive assembly allows effective lubrication to be achieved economically and reliably.

The present invention is directed particularly but not exclusively to the problem of providing an accurate and long life support for planet gears in a manner which is economical and which may be utilized on a wind turbine assembly.

In accordance with one aspect of the present invention a planetary type gear transmission unit comprises sun, planet and ring gears and a planet carrier, said planet carrier comprising a planet bogie plate which supports and locates circumferentially spaced planet gear bearings on which planet gears are mounted, and at least some of said bearings being taper roller type bearings.

The gear unit may comprise planet gears which are arranged in axially aligned pairs. That is, the planet gears of a pair may be co-axially arranged.

The bearings may support respective pairs of aligned planet gears, typically the two gears of each pair being positioned at opposite sides of the plate.

The bearing(s) for each circumferentially spaced planet gear position may be supported on a shaft which in use is able to self adjust in said angular position relative to the bogie plate.

Alternatively said shaft may be substantially rigidly secured to the bogie plate. The bogie plate may be of a kind which, in consequence of elastic deformation, is compliant to an extent sufficient to allow self adjustment of the angular position of the shaft relative to the axis of rotation of the ring gear, for example in the case of a shaft which is substantially rigidly secured to the bogie plate.

As considered in an axial direction parallel with the axis of rotation of the planet carrier, a main bearing for rotatably supporting a ring gear relative to a planet carrier may lie at a position substantially aligned axially with the axial position of at least the ring gear of the gear transmission unit.

In some embodiments of the invention it may be preferred that the sun, planet and ring gears lie in a transverse plane (perpendicular to the rotation axis of said rotational forces) which also contains said main bearing.

The ring gear may provide axial and radial locations for the main bearing. The ring gear may have a radially outer surface of a stepped profile to define a shoulder for axial location of an inner bearing ring of the main bearing. The inner bearing ring may be secured axially and non-rotatably between said shoulder a supporting structure.

The ring gear may be provided with a reinforcing ring, and said reinforcing ring may extend axially and or radially beyond the toothed surface of the ring gear. Said reinforcing ring may provide an axial location of the main bearing.

The main bearing may comprise a double taper bearing, and said double taper bearing may comprise a single outer bearing ring. The double taper bearing may comprise rollers arranged in an O configuration in which the rollers of one series increase in diameter in a direction away from the rollers of the other series of the pair.

In a yet further of its aspects the present invention provides a wind turbine comprising rotors, a generator and a drive assembly comprising a gear transmission unit of a type in accordance with the present invention. In said drive assembly the ring gear typically may be supported non-rotatably relative to supporting structure.

A part of the gear transmission unit, e.g. a housing thereof, may be arranged to support an electrical generator.

The invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings in which: -

Figure 1 is an elevation view of a wind turbine having a gear transmission unit of the present invention;

Figure 2 is a sectional view of part of a gear transmission unit;

Figure 3 shows part of Figure 2 in more detail, and

Figure 4 shows a particular feature of the present invention.

A wind turbine 10 (see Figure 1) comprises a gear transmission unit 11 which acts to transmit torque from rotor blades 12 and a rotor hub 14 to an electrical generator 13, the gear transmission unit comprising an epicyclic gear unit. The gear transmission unit and generator are housed in and supported by a nacelle 15.

The gear transmission unit 11 is now described in more detail with reference to Figures 2 and 3. The gear transmission unit 11 comprises an epicyclic gear unit having four circumferentially spaced planet gears 25, a sun gear 27 a planet carrier 28, and a ring gear 24 which is non-rotatably mounted relative to the nacelle structure 15.

The sun gear is connected to an output shaft (not shown) which connects either to a further gear unit or direct to the rotor of the generator 13.

The radially outer surface 29 of the ring gear 24 provides location and support for the inner ring 30 of a main bearing 23.

The outer ring 31 of the main bearing has secured thereto the rotor hub 14 and, interposed between the rotor hub and ring 31, the outer region 22 of the planet carrier 28.

In a prior proposed construction the planet carrier 28 of Figure 3 comprises four bearing support studs 26 uniformly circumferentially spaced to locate bearings 32 which rotatably support the four planet gears 25. The planet carrier 28 has an annular region 33 which extends radially between the radial position of the bearing studs 26 and the outer region 22 and is designed to be relatively stiff, in a circumferential direction about the Y axis, for transmission of torque between the region 22 and the bearing studs 26, but to be relatively flexible about the X and Z axis.

In accordance with the present invention the planet carrier 28 is replaced by a planet carrier 41 (see Figure 4) provided, in this embodiment, with three integral and uniformly circumferentially spaced studs 42 which support a planet bogie plate 43. The planet bogie plate 43 provides support for three circumferentially uniformly spaced shafts 44 arranged each (as viewed in the plane of Figure 4) to self adjust in angular position on the plate 43. Each shaft 44 provides support, at opposite sides of the plate 43, for a pair of taper roller

bearings 45, 46 about which each of a pair of planet gears 47, 48 are rotatably mounted for engagement with the ring gear 49.

In the aforedescribed construction the torque acting on the rotor hub 14 under action of the rotor blades 12 is transmitted to the planet gears 47, 48 via the planet carrier 41 rotatably mounted at is outer region to the outer ring 31 of bearing 23. Bending moments and axial forces in the Y direction exerted by the rotor hub in this construction are transmitted direct to the bearing 23. The flexibility of the annular portion 33 of the planet carrier 28 assists to substantially isolate those forces from the planet gears.

The present invention thus teaches, in its broadest aspect, that a bogie of a planet carrier is provided with roller bearings which are of the taper type for the support of planet gears.

The present invention teaches in another of its aspects that the planet gears may be supported, via their bearings, on a shaft of the so-called flexpin type, such as described in GB 1,101,131 in the context of a simple type of epicyclic gear. The present invention, in this one of its aspects, perceives that special benefit may be achieved by utilising a shaft of the flexpin type in the context of an epicyclic gear unit having a planet bogie. This benefit may be attained irrespective of whether, as described above, the planet gear bearings are taper roller bearings, or whether they are cylindrical roller bearings. Use in constructions having other bearing arrangements, and such as spherical bearings, is not excluded.

A variation of the Figure 4 construction to utilise a flexpin as the shaft 44 thereof is now discussed in more detail.

Figure 5 shows the basic layout. The back-plate 5, i.e. bogie plate, drives the inner part of the planet shaft 1 which in turn carries the outer part or sleeve (4), the planet bearing 2 and the planet 3. The function of the flexpin in the context of application to a bogie is now described briefly with reference to Figure

6. An external force (for instance the tangential planet forces) will cause the inner shaft 1 to bend as a result of the bending moment F*y. Point "A" is offset by a distance "x" from the application point of the force causing a moment F*x. This bending moment at "A" works in the opposite direction to the first one and thus causes the outer sleeve to counter rotate in the direction of the second moment.

The amount of compensation will depend upon the distances x and y as well as the designs of the inner shaft and sleeve. The use of the flexpin is advantageous for load distribution over the tooth flanks (KHß) as well as load sharing between the planets in the planetary cell (K_gamma). The equality of loads between the planets (K_gamma) will be inversely proportional to the stiffness of the planet shafts and it is thus preferred to make the planet shafts as flexible as possible.

The amount of compensation could be equal at both sides of the central bogie plate but does not have to be. Particularly if the gear unit comprises a helical sun gear it may be advantageous to choose different amounts of compensation in order for the left and right planets to better follow the helical deformation of the sun shaft under load. (Due to torsion). This would not be possible in the classical flexpin designs as there is only one row of planets, but is possible in the application to a planet bogie.

When using helical teeth in a planetary cell, a moment is created by the axial components of the normal tooth forces in the ring gear and sun meshes respectively (see Figure 7). This unwanted effect causes the planets to skew and the amount of skewing is inversely proportional to the planet shaft stiffness. With a flexpin design, the planet shaft assembly (inner shaft and sleeve) is less stiff than in conventional designs and will thus cause more planet skewing. This is the reason that the flexpin is usually only used with spur gearing. A possible solution to this problem could come from making the planet shaft (inner or combination)

an-isotropic as far as it's stiffness goes. Figures 8 to 10 show a planetary system employing such a design. The inner shaft is made in such a way as to still allow the needed flexibility in the tangential direction (see Figure 9) but to be as stiff as possible in a plane normal to the tangential direction (Figure 10). In this way it could become possible to use the flexpin in combination with helical teeth.